

# The Inevitable Rise of NVM in Computing

**Jim Handy**

**Nonvolatile Memory Seminar**

**Hot Chips Conference**

**August 22, 2010**

**Memorial Auditorium**

**Stanford University**



**OBJECTIVE  
ANALYSIS**

# OBJECTIVE ANALYSIS

Semiconductor Market Research

- Market consulting/research firm
  - Market analysis, strategies, white papers
- Highly-respected lead analysts
  - Jim Handy: Memories
  - Tom Starnes: Processors
- Industry experience & 25+ years in field
- Reports, Competitive Analysis, Consulting

# Agenda

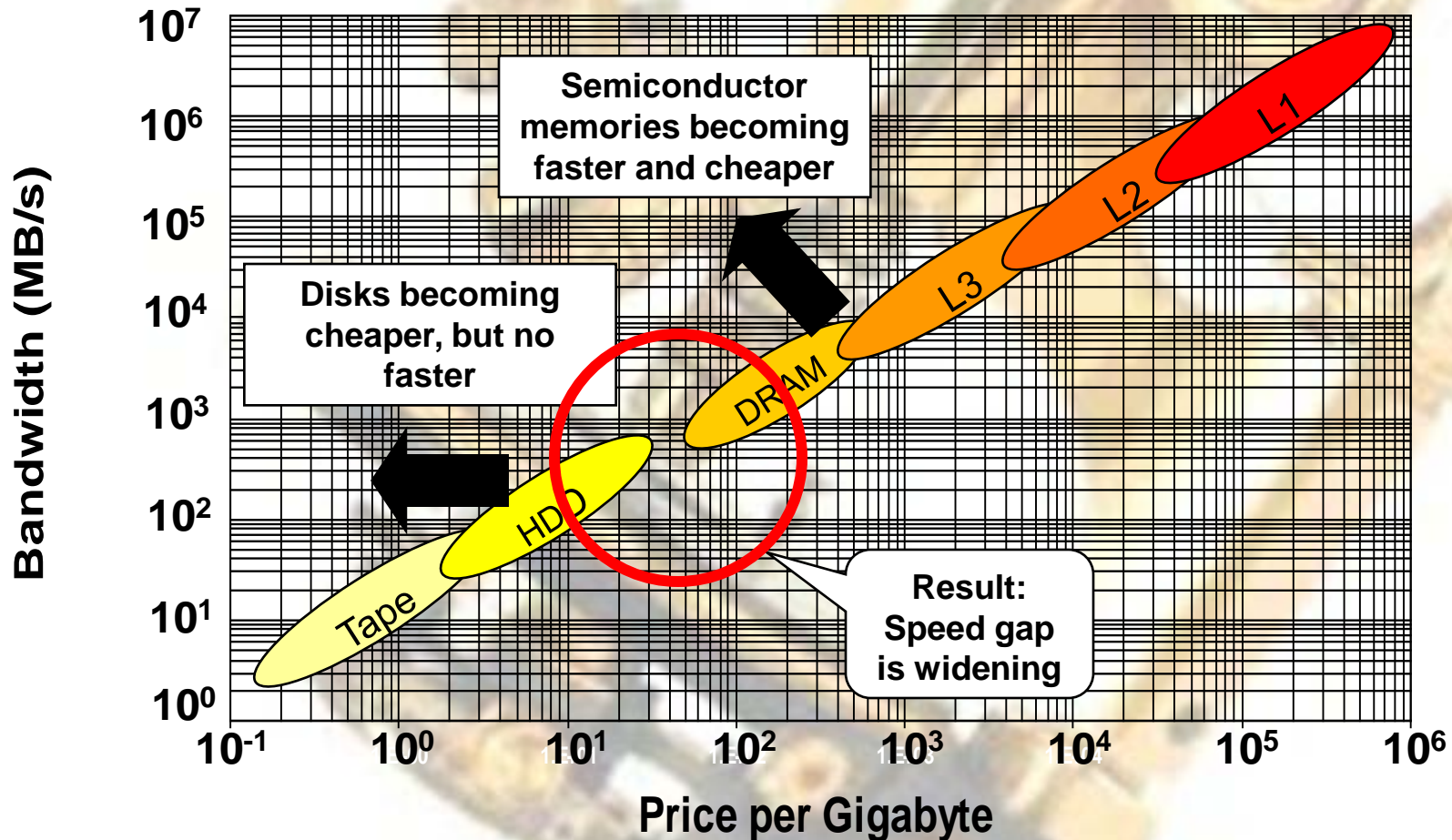
- SSDs: Why now?
- Where do they fit?
- How will flash penetrate the PC?
- What challenges does flash present?

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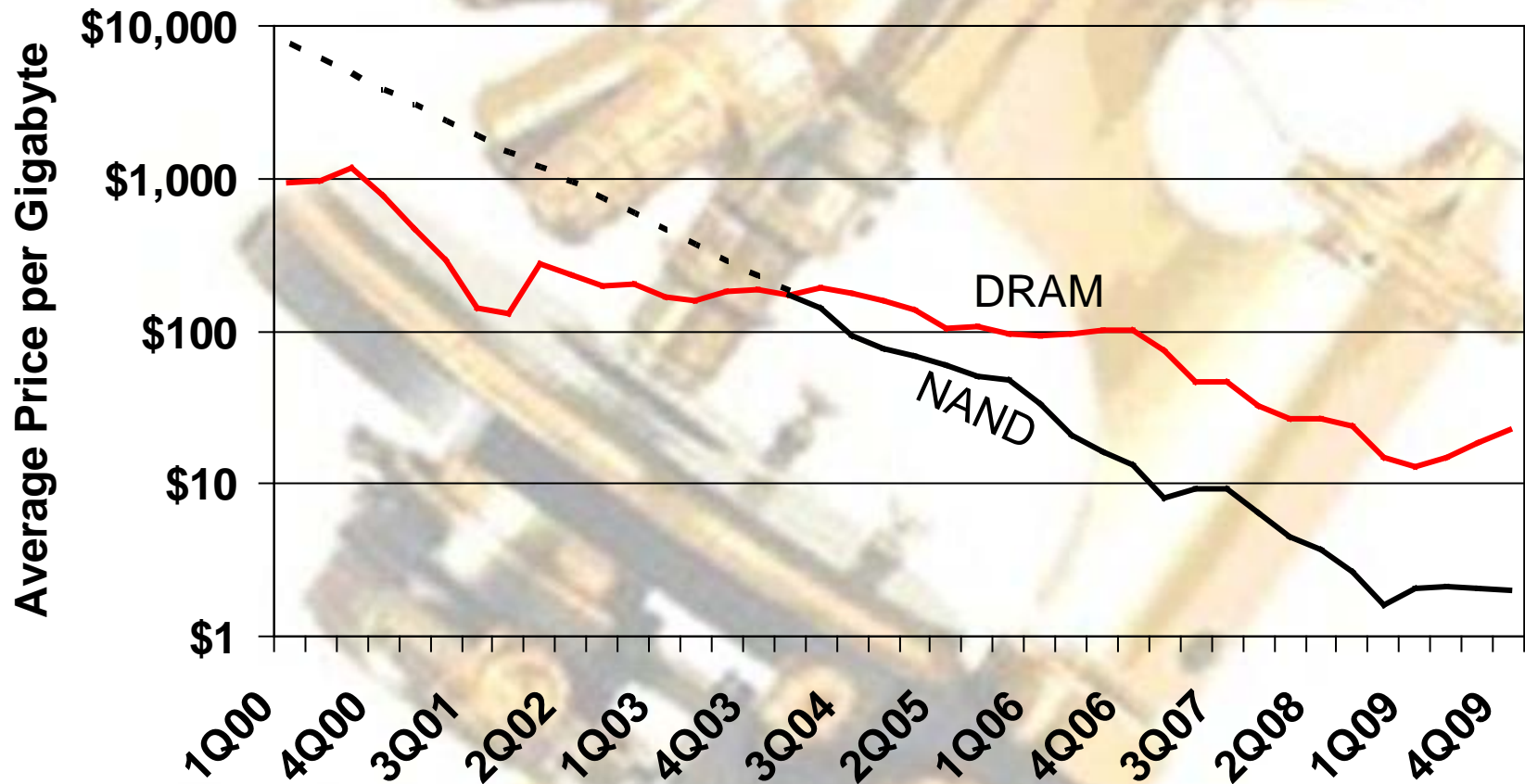


# The DRAM/HDD Speed Gap



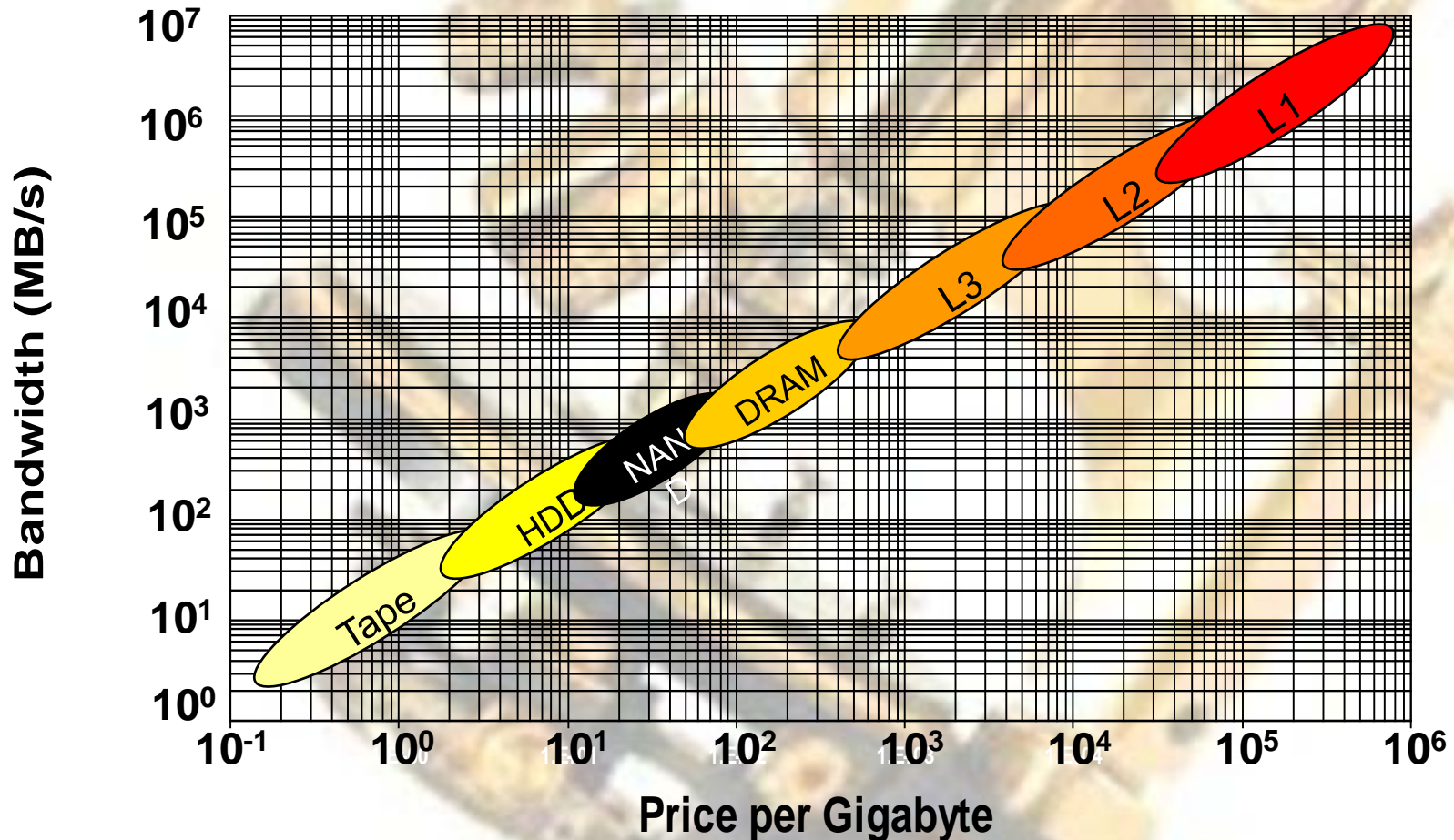
From: *Solid State Drives in the Enterprise*

# NAND Shot Past DRAM's Price per GB



From: *Hybrid Drives: How, Why, & When?*

# Now NAND Fits in Computers



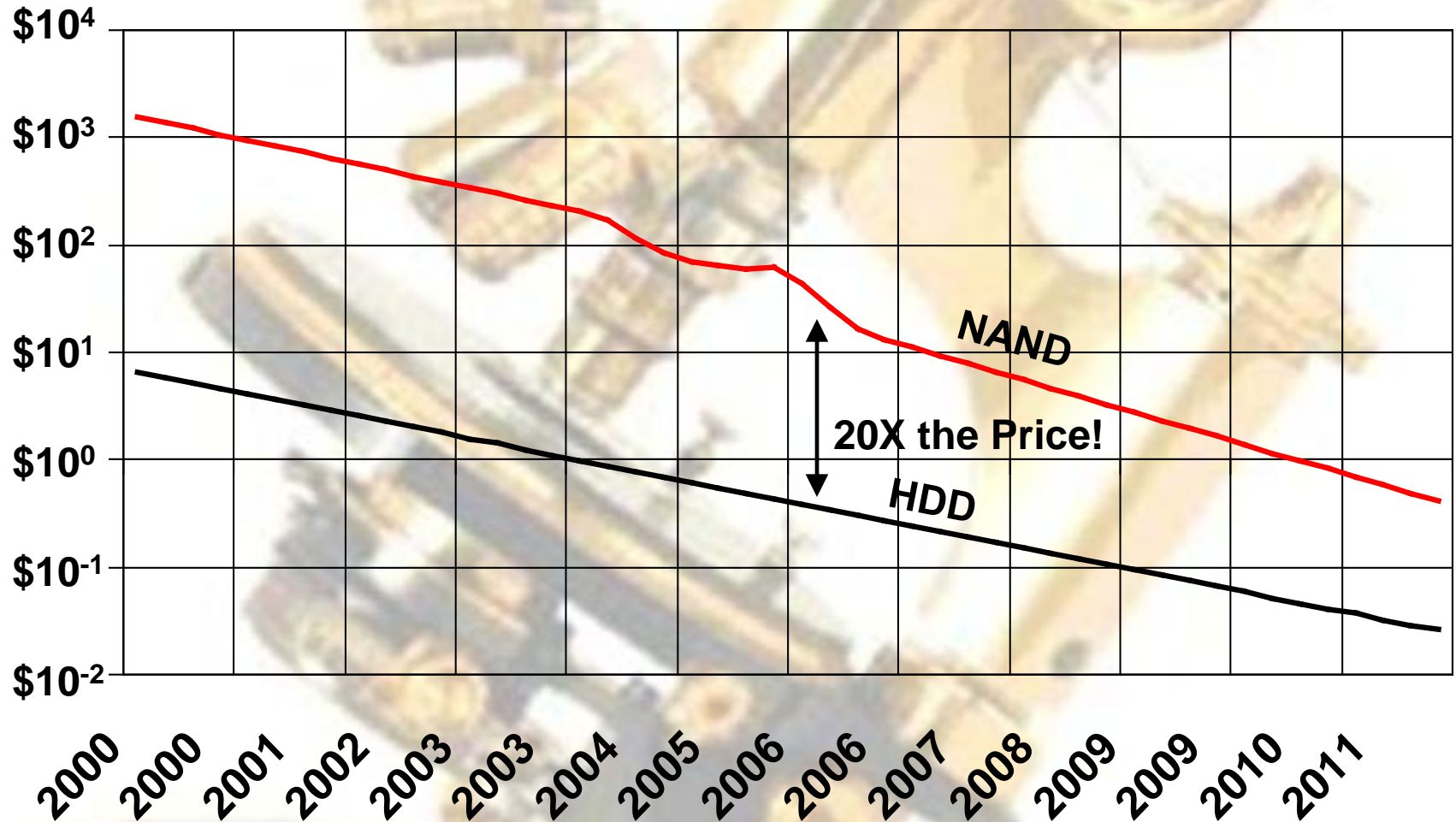
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# NAND Unlikely to Match HDD \$/GB

Price per Gigabyte



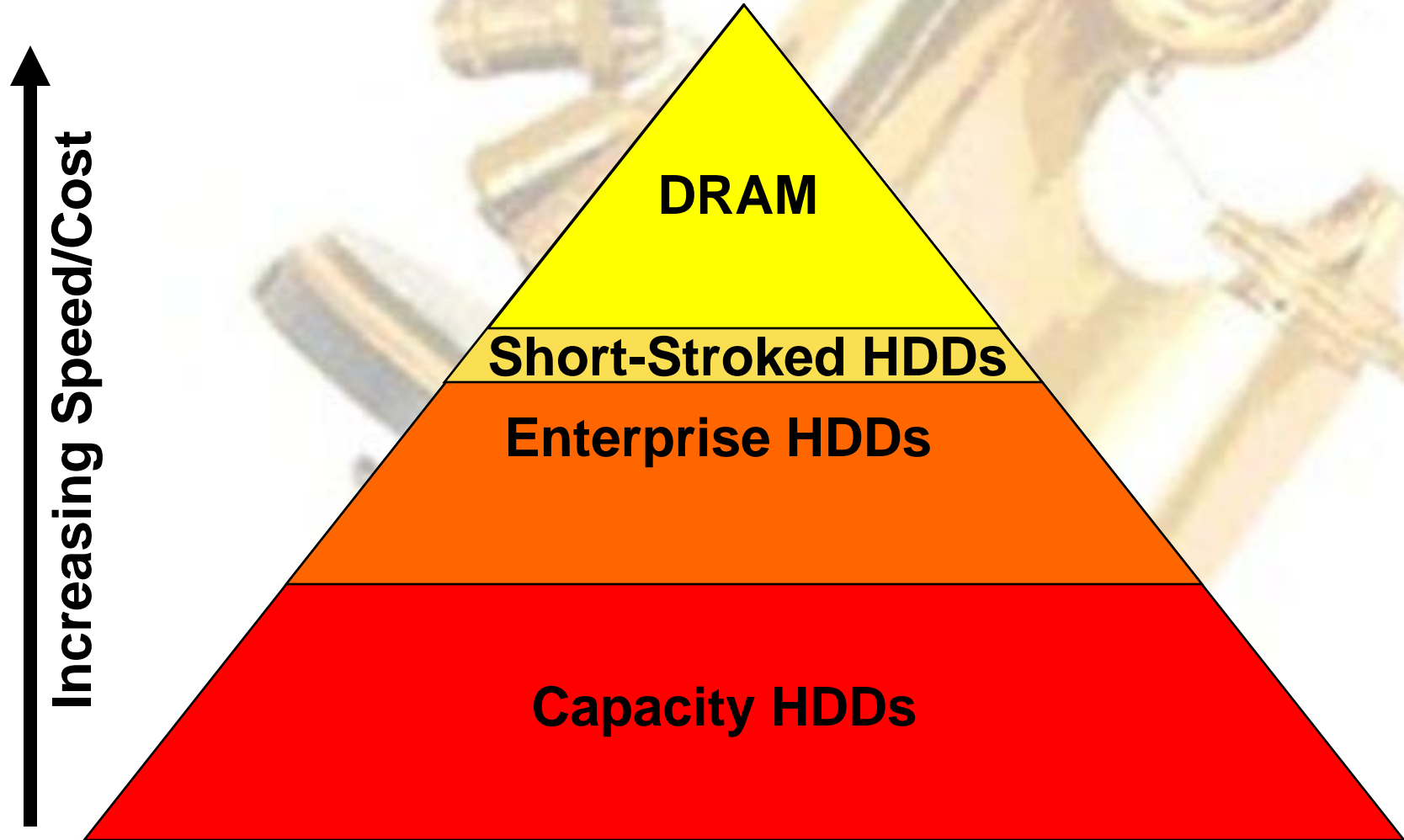
From: *Understanding the NAND Market*



# Agenda

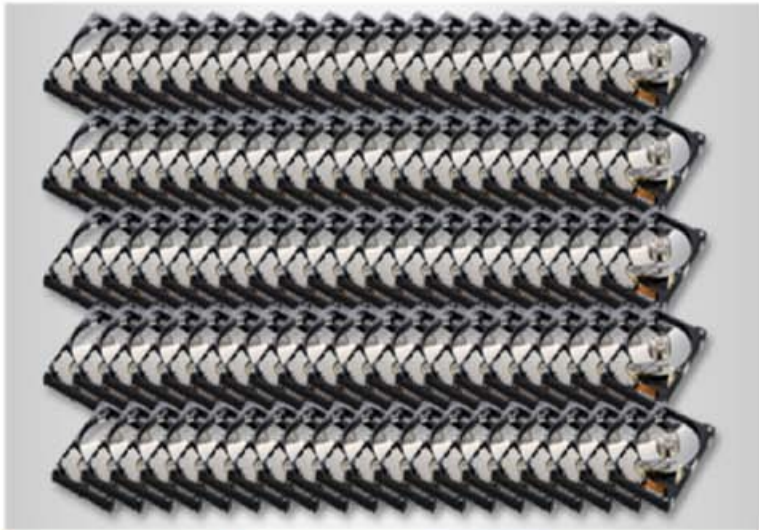
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# Storage Hierarchy



# SSDs in the Enterprise

## 100 Enterprise HDDs



Capacity: 30TB  
Performance: 30K IOPS  
Cap/Op-X: \$55,000 – 1.75kWh

## Hybrid Storage Pool

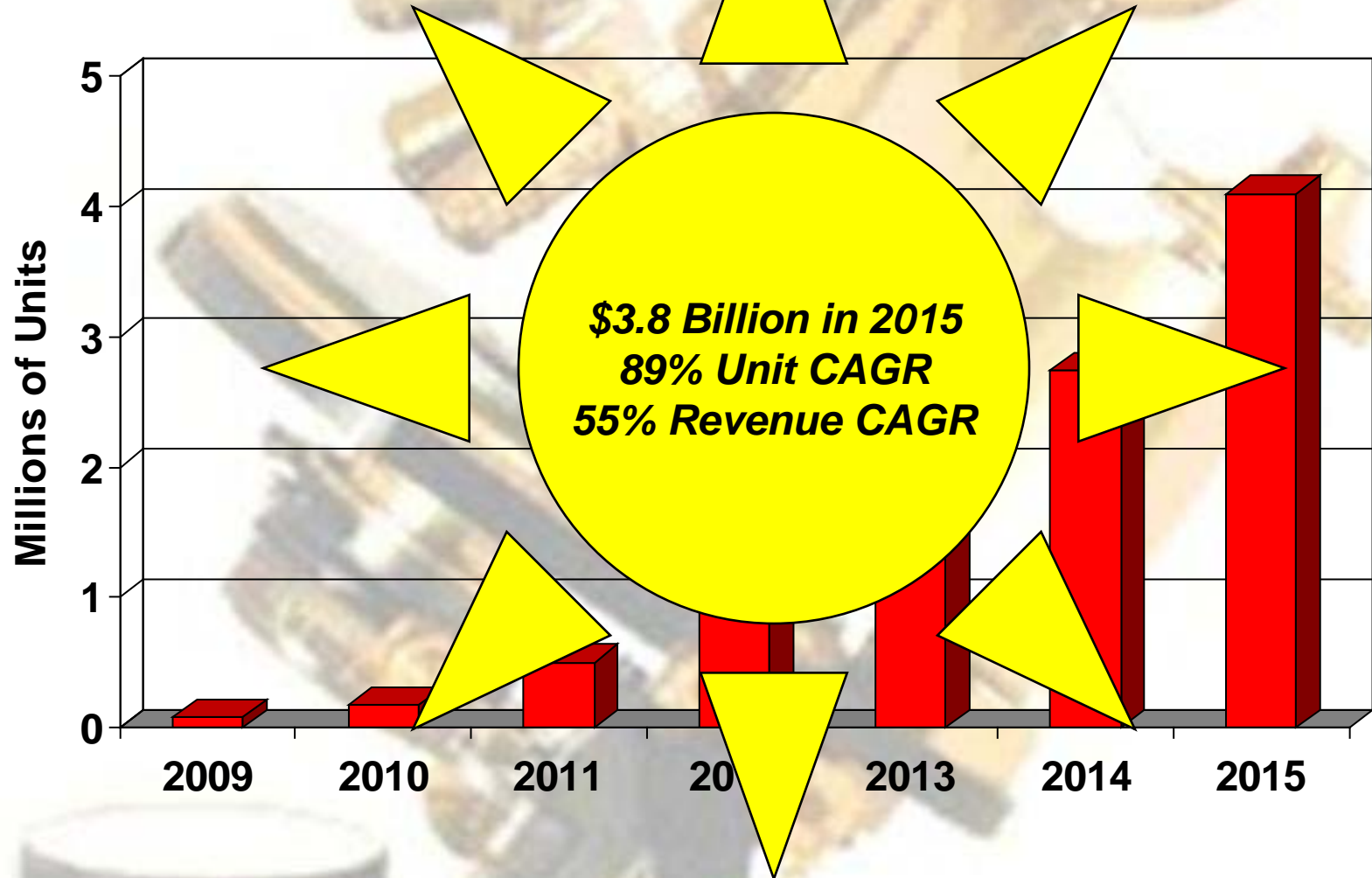


Capacity: 30TB  
Performance: 30K IOPS  
Cap/Op-X: \$6,040 - 0.392kWh

1/5th  
the Power  
1/10th  
the Cost

Source: Sun Microsystems, August 2008

# Enterprise SSD Forecast

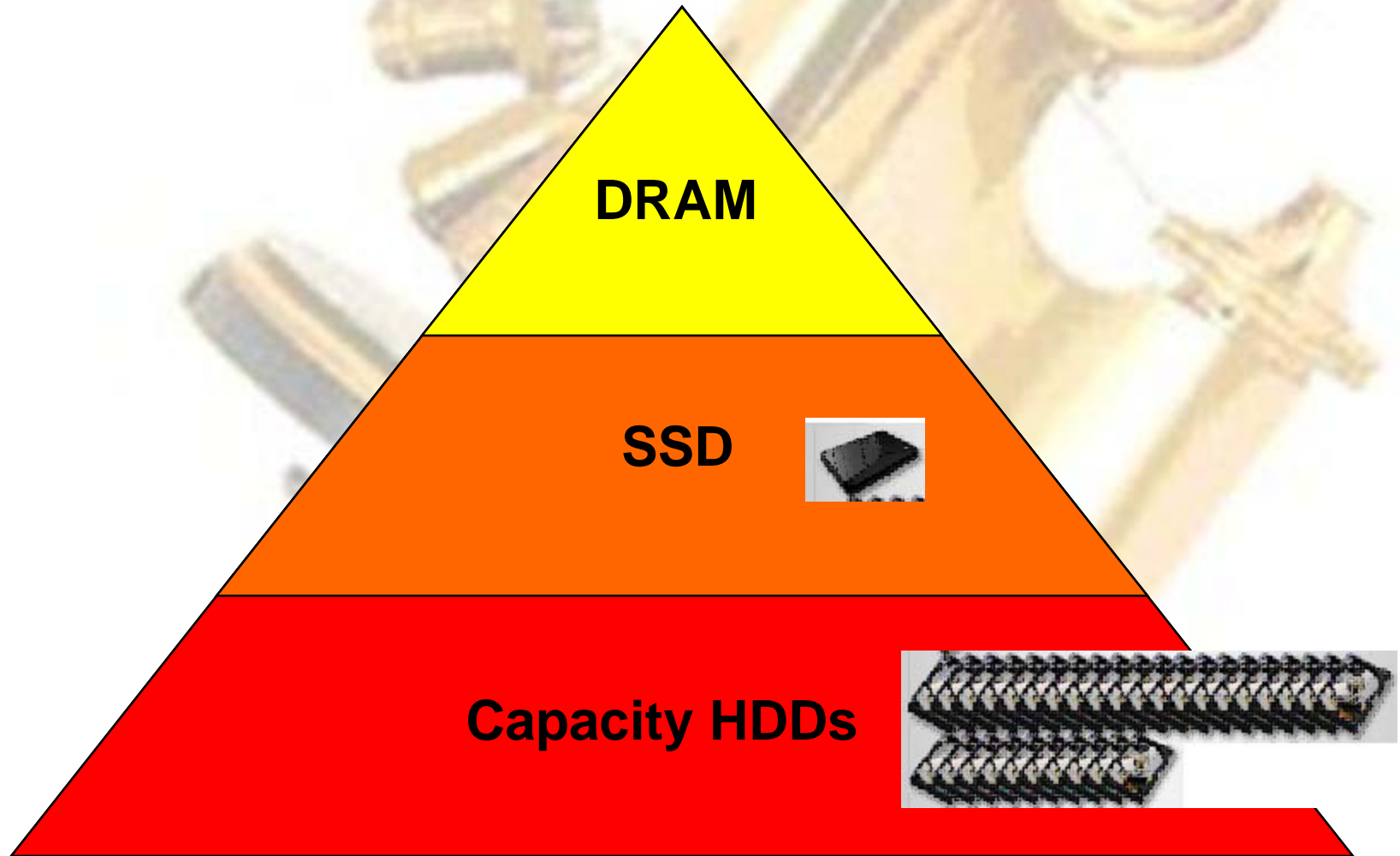




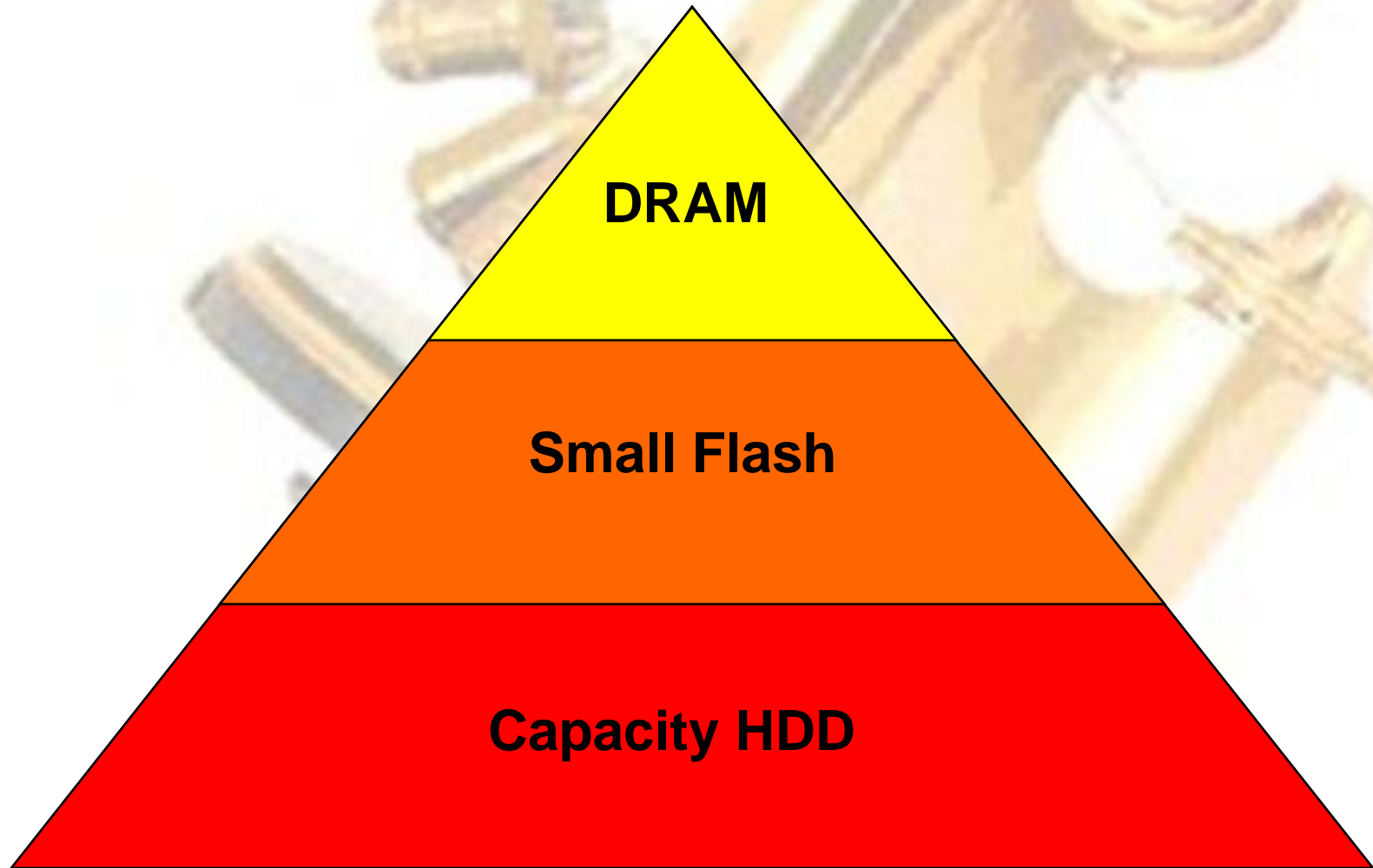
# Agenda

- SSDs: Why now?
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- **How will flash penetrate the PC?**
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# Flash in Enterprise Storage



# The Same Model in a PC



# Many Alternatives Coming

- Intel Braidwood
  - NAND on the motherboard
    - Managed by chipset & firmware
  - Preceded by Robson/Turbo Memory
- Seagate Momentus XT Hybrid HDD
  - Uses internal NAND management
- NVELO (formerly Denali) Dataplex
  - NAND management for SSD/HDD combo
- Others coming soon



# Why Early Attempts Failed

- Robson/Turbo Memory
  - Small size (4MB)
  - Poor Windows Vista Support
    - Invoking support sometimes degraded performance
- Hybrid HDD
  - As above: Small size and Vista problems
  - Weak industry support: Samsung & Seagate

# Taking Control of the Flash

- Intel's Braidwood
  - Firmware, chipset, drivers
  - NAND on ONFi DIMMs
- Seagate Momentus XT
  - HDD controller manages flash
  - Flash sits inside HDD
- NVELO's Dataplex
  - Just sell the control software
  - OEM decides whose HDD & flash to use

# Agenda

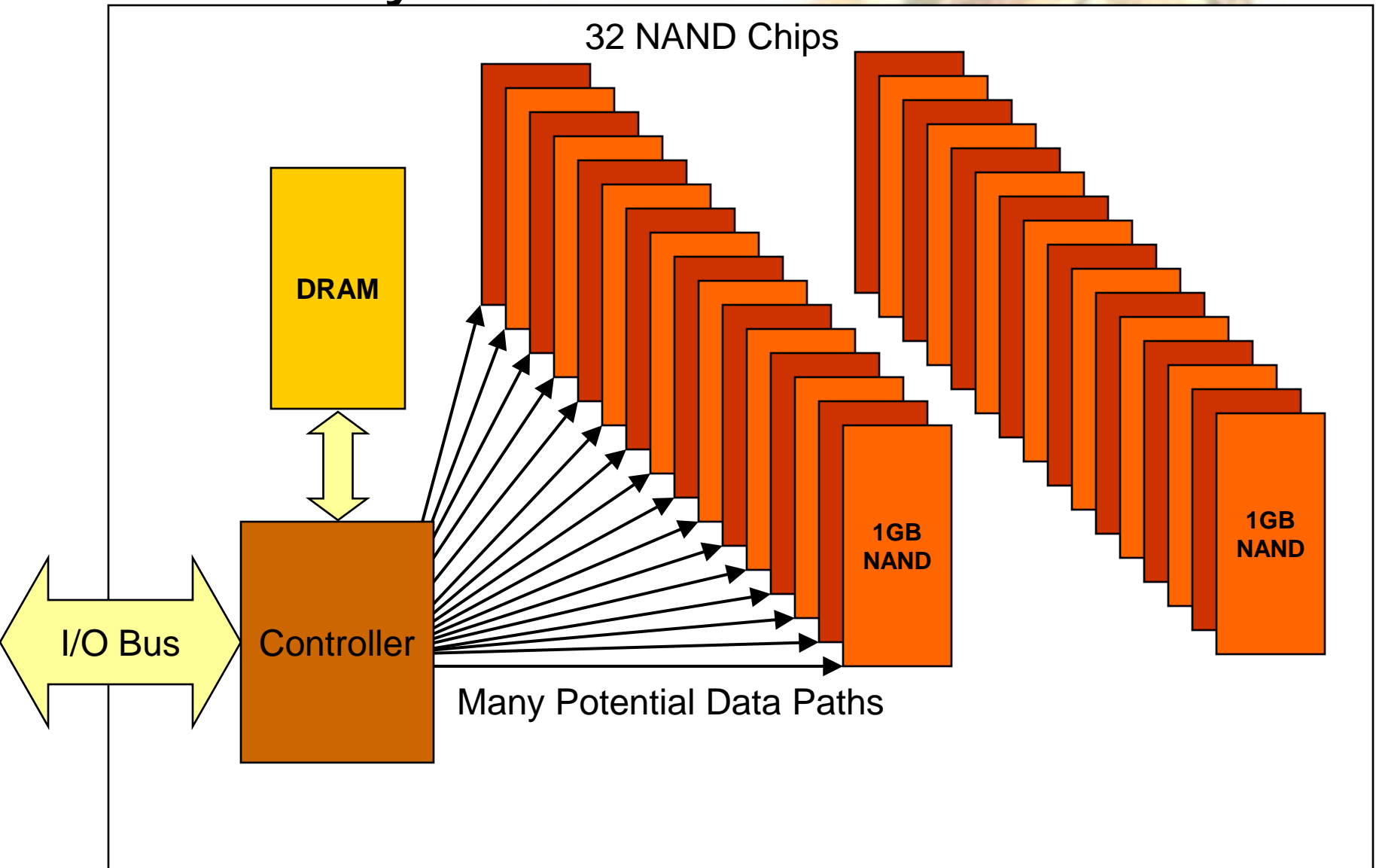
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# Problem 1: HDD Interfaces

- HDD interfaces designed around HDDs
  - Slow I/O needs queuing
  - Single internal data path
  - Overwrite old data at any time
- SSDs are really different:
  - Very fast reads
  - Erase before write
  - Multiple internal data paths
  - Wear-out mechanism



# Why the Interface Matters



# Problem 2: Erase & Write Timing

- Erase required before write
  - HDD simply overwrites data
  - Requires erase strategy
- Slower write than read
  - Page read  $\sim 25\mu\text{s}$  setup, then  $50\text{ns}/\text{byte}$
  - Page write  $\sim 1\text{ms}$
  - Block erase  $\sim 5\text{ms}$
- Today's software expects balanced R/W

# How Software Can Help

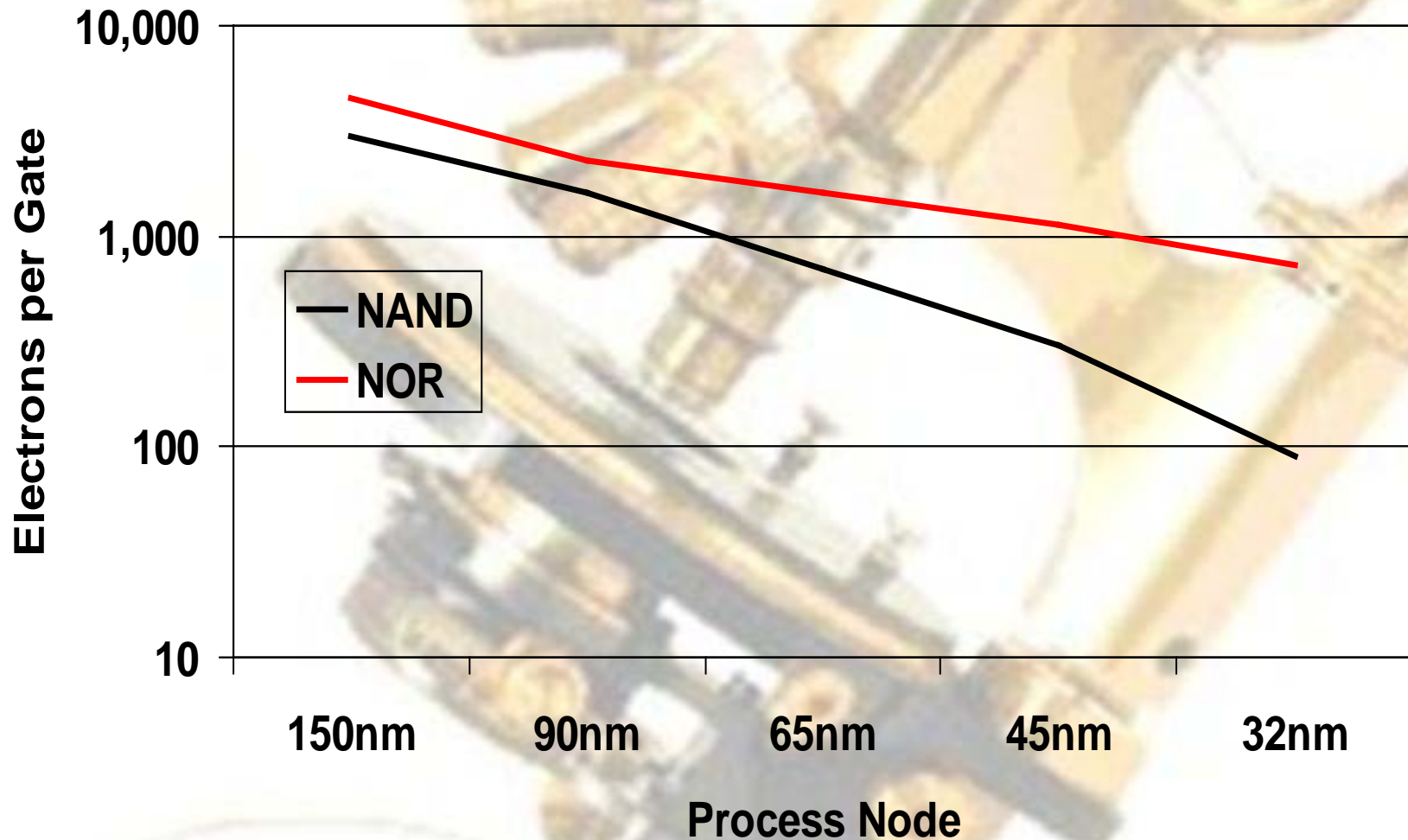
- Frequent reads/infrequent writes
- Cues for housekeeping
  - “Trim” command today
- Understanding the hierarchy
  - Fast things onto flash
  - HDD stores other stuff
  - Just like cache memory, virtual memory, etc.

# Problem 3: NAND Scaling Limit

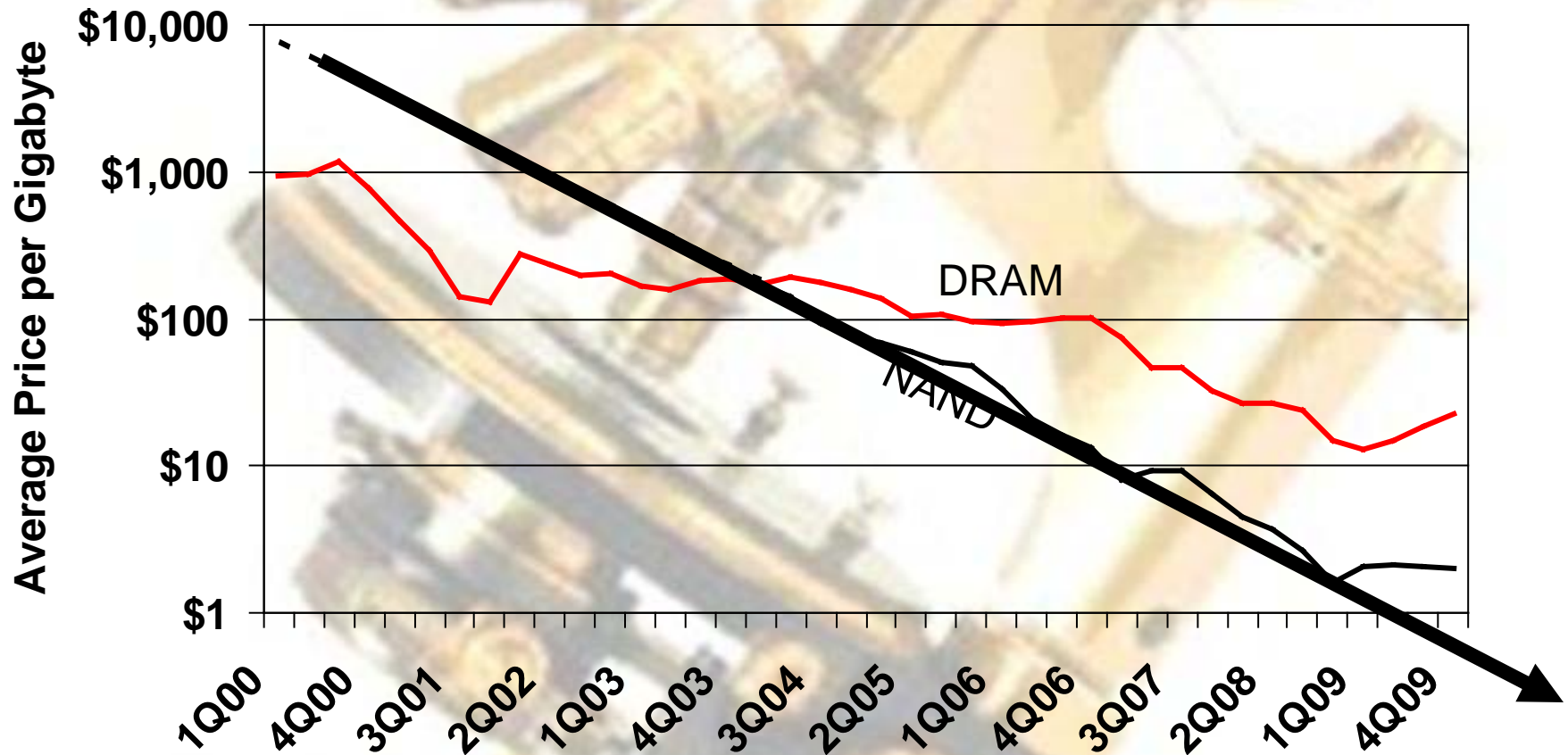
- NAND will reach a limit
  - Too few electrons per gate
  - Needs constant shrinks for cost reductions
  - 4-bit/cell hard to make
    - This may be the maximum possible
- Other technologies will scale past NAND
  - PCM, MRAM, RRAM, FRAM....
    - Not yet clear which will win



# Too Few Electrons per Gate

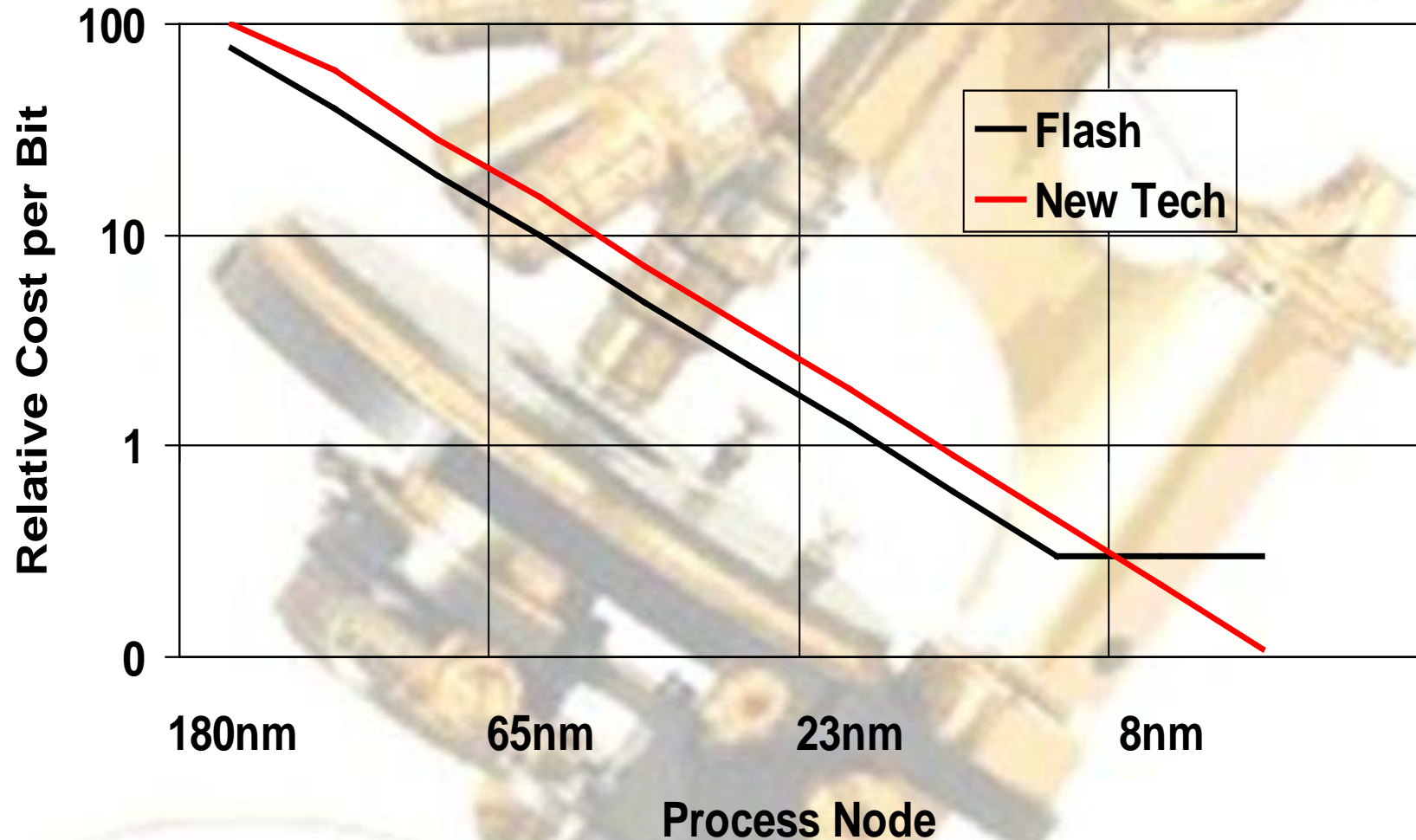


# How to Maintain this Inertia?



From: *Hybrid Drives: How, Why, & When?*

# How Alternatives will Emerge



# Summary

- Flash belongs in all computers
  - So does HDD
- Many changes will result
  - Interface
  - Software
  - Even the memory technology!





# Thank You!

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